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Revision 2

Type A Nuclear Logging Data Acquisition and Processing for Operable Units 7-13/14 and 7-10

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Type A Nuclear Logging Data Acquisition and Processing for Operable Units 7-13/14 and 7-10

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ABSTRACT

Between June 1999 and July 2001, the Idaho National Engineering and Environmental Laboratory Environmental Restoration Program installed a total of 148 Type A probes into the buried waste in the Subsurface Disposal Area at the Radioactive Waste Management Complex. Type A probe installation and logging was performed to address a variety of objectives in the Subsurface Disposal Area waste pits that included the following:

- Substantiate the location of waste shipments that have been tentatively located using waste inventory records and surface geophysics
- Identify areas with high relative contamination levels suitable for detailed in situ studies
- Identify areas having waste characteristics suitable for pilot remediation studies.

The Type A logging program produced a large quantity of unique subsurface data that has provided an improved understanding of the buried waste environment. This report is designed to document key aspects of the logging program and provide an understanding of the data to construct an efficient and useful archive.

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1. INTRODUCTION

Between June 1999 and July 2001, the Idaho National Engineering and Environmental Laboratory Environmental Restoration Program installed a total of 148 Type A probes in buried waste in the Subsurface Disposal Area (SDA) of the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering and Environmental Laboratory (INEEL). Type A probe installation and logging was performed to address a variety of objectives in the SDA waste pits, including the following:

- Substantiate the location of waste shipments that tentatively have been located using waste inventory records and surface geophysics

- Identify areas with high relative contamination levels suitable for detailed in situ studies

- Identify areas having waste characteristics suitable for pilot remediation studies.

The Type A logging program produced a large quantity of unique subsurface data that has provided an improved understanding of the buried waste environment. The locations of the RWMC and the SDA are shown in Figures 1 and 2, respectively.

1.1 Purpose

This report is designed to document key aspects of the Type A logging program and provide an understanding of the data to construct an efficient and useful archive.

1.2 Scope

The information presented in this report includes the following:

- A summary of Type A probe installation and logging.

- A description of logging tools and data acquisition hardware.

- A description of GTS Duratek-performed data analysis.[a]

- A description of GTS Duratek tool calibration data, including known limitations.

- Recommendations for database records and structure.

NOTE: *This report does not address logging data interpretation.*

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a. GTS Duratek is located in Richland, Washington, and performs nuclear logging services at the U.S. Department of Energy (DOE) Hanford Site near Richland. GTS Duratek formerly was called Waste Management Federal Services or Waste Management Technical Services. Some older reports discussing tool development, tool calibration, and operating procedures are published by Pacific Northwest National Laboratory and Westinghouse Hanford Company.

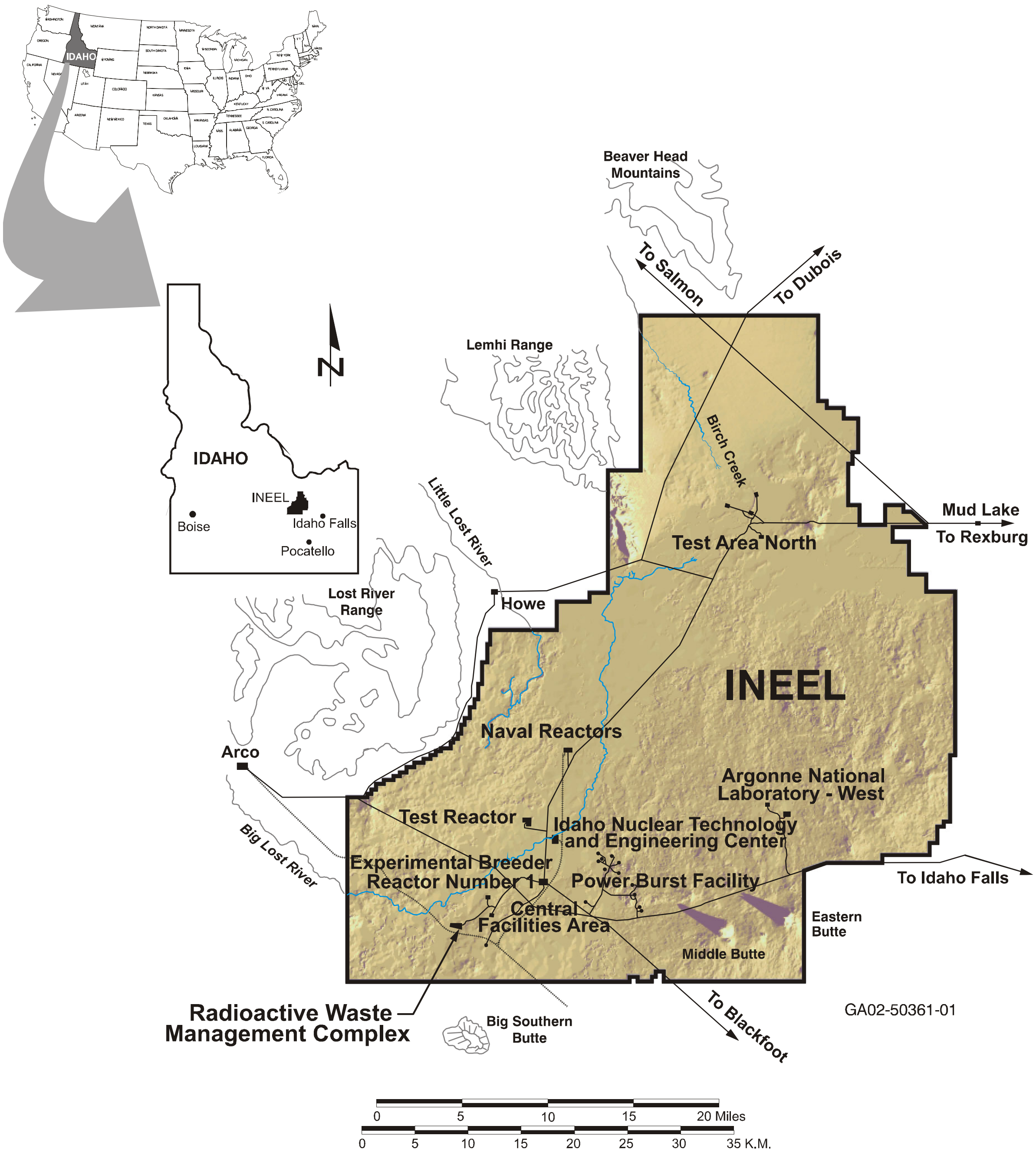

Figure 1. Location of the Radioactive Waste Management Complex at the Idaho National Engineering and Environmental Laboratory.

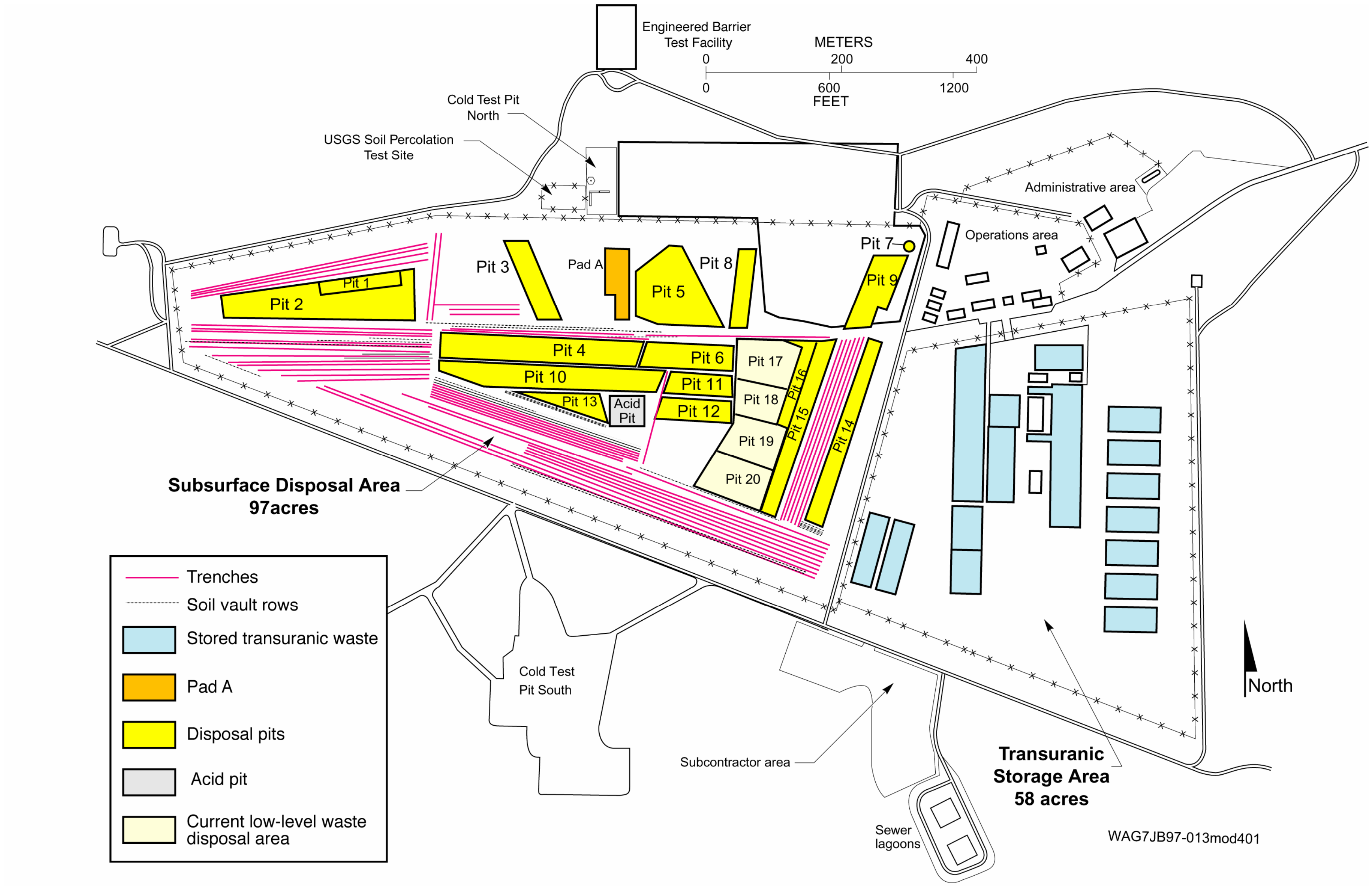

Figure 2. Location of the Subsurface Disposal Area in the Radioactive Waste Management Complex.

1.3 Background

Between 1999 and 2001, the INEEL Environmental Restoration Program installed 148 Type A probes in buried waste pits in the SDA. The term “Type A probe” refers to probes installed at the SDA specifically to implement downhole nuclear logging surveys. The probes are sealed, steel casings 14 cm (5.5 in.) in diameter, designed to accommodate geophysical logging tools for investigating in situ conditions in the subsurface waste zones. The standard geophysical logging suite included four tools: (1) a passive spectral gamma tool to detect anthropic and natural gamma-emitting radionuclides, (2) a neutron-activated gamma tool to detect neutron-capture gammas emitted by specific elements such as chlorine, (3) a neutron-neutron moisture tool to measure in situ soil moisture, and (4) a passive neutron tool to detect neutrons produced by spontaneous fission and alpha-neutron reactions initiated by radionuclides in the buried waste. A fifth logging tool, the azimuthal gamma-ray tool, was deployed on a selective basis to measure the direction of incident gamma radiation. The downhole logging tools used at the SDA were developed and operated by GTS Duratek.

Type A probe installation and logging was performed to address a variety of objectives in several different SDA waste pits. The Type A logging program produced a large quantity of unique subsurface data that have provided an improved understanding of the buried waste environment. These data also have been useful for addressing quantitative issues relating to specific buried waste types such as the chlorine content of Rocky Flats Plant[b] 743-series[c] sludge.

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b. The Rocky Flats Plant is located 26 km (16 mi) northwest of Denver. In the mid-1990s, it was renamed the Rocky Flats Environmental Technology site. In the late 1990s, it was again renamed, to its present name, the Rocky Flats Plant Closure Project.

c. The waste is called 743-series waste because it was processed into sludge in Rocky Flats Plant Building 774 and was later coded at the INEEL as Content Code 3 organic waste to distinguish it from different types of waste from Rocky Flats Plant Building 774 shipped to the INEEL.

2. SUMMARY OF LOGGING ACTIVITIES

2.1 Type A Probe Summary

A total of 148 Type A probes were installed in or adjacent to Pits 4, 5, 9, and 10 between June 1999 and July 2001. The term "Type A probe" refers to probes installed at the SDA specifically to implement downhole nuclear logging surveys. Type A probes have a hollow, steel construction, an outside diameter of 14 cm (5.5 in.), a 1.3-cm (0.5-in.) wall thickness, a sealed probe tip, and a cap. Geophysical logging was conducted in 138 of these probes. The remaining 10 probes were not logged because the presence of a resistive subsurface layer prevented them from reaching sufficient depth for logging. Table 1 gives a complete summary of the name, depth, and logging status for all Type A probes discussed in this report.

Table 1. Type A probe summary.

Type A Probe	Total Depth (ft)	Geophysical log types				
		PG	NG	PN	MO	AZ
741-01	5.9					
741-02	18.1	X	X	X	X	X
741-03	20.3	X	X	X	X	X
741-04	24.3	X	X	X	X	X
741-05	6.4					
741-06	18.0	X	X	X	X	
741-07	6.3					
741-08	22.3	X	X	X	X	X
741-08-A	20.8	X	X	X	X	
741-08-B	21.8	X	X	X	X	
741-09	14.3	X	X	X	X	
743-01	17.2	X	X	X	X	
743-02	20.7	X	X	X	X	
743-03	19.5	X	X	X	X	
743-04	25.5	X	X	X	X	
743-05	27.0	X	X	X	X	
743-06	26.2	X	X	X	X	
743-07	25.3	X	X	X	X	
743-08	25.3	X	X	X	X	X
743-08-01	25.6	X	X	X	X	
743-08-02	25.0[a]	X	X	X	X	
743-08-03	26.3	X	X	X	X	
743-08-04	25.1	X	X	X	X	
743-08-05	25.0	X	X	X	X	
743-08-06	25.1	X	X	X	X	
743-09	24.3	X	X	X	X	
743-10	25.8	X	X	X	X	
743-11	25.5	X	X	X	X	
743-12	25.0	X	X	X	X	

Table 1. (continued).

Type A Probe	Total Depth (ft)	Geophysical log types				
		PG	NG	PN	MO	AZ
743-13	25.6	X	X	X	X	
743-14	23.0	X	X	X	X	
743-15	21.9	X	X	X	X	
743-16	16.2	X	X	X	X	
743-17	20.7	X	X	X	X	
743-18	21.0	X	X	X	X	
743-19	4.2					
743-20	16.3	X	X	X	X	
743-21	14.8	X	X	X	X	
743-22	21.4	X	X	X	X	
743-23	8.4	X	X	X	X	
743-24	23.5	X	X	X	X	
743-25	17.8	X	X	X	X	
743-32	12.1[a]	X	X	X	X	
743-33	12.1	X	X	X	X	
743-34	11.9	X	X	X	X	
743-35	16.4	X	X	X	X	
743-36	25.8	X	X	X	X	
743-37	25.8	X	X	X	X	
743-38	15.5	X	X	X	X	
743-39	19.8[a]	X	X	X	X	
743-40	18.4[a]	X	X	X	X	
743-41	21.5[a]	X	X	X	X	
743-42	22.2	X	X	X	X	
DU-01	14.3	X	X	X	X	
DU-02	14.8	X	X	X	X	
DU-03	14.5	X	X	X	X	X
DU-04	14.0	X	X	X	X	
DU-05	18.3	X	X	X	X	
DU-06	18.5	X	X	X	X	
DU-07	14.5	X	X	X	X	
DU-08	18.7	X	X	X	X	X
DU-08-A	18.1	X	X	X	X	
DU-08-B	17.6[a]	X	X	X	X	
DU-09	18.5	X	X	X	X	
DU-10	17.3	X	X	X	X	X
DU-10-A	17.0	X	X	X	X	
DU-10-B	17.2	X	X	X	X	
DU-11	18.1	X	X	X	X	
DU-12	18.3	X	X	X	X	
DU-13	18.1	X	X	X	X	

Table 1. (continued).

Type A Probe	Total Depth (ft)	Geophysical log types				
		PG	NG	PN	MO	AZ
DU-14	17.3	X	X	X	X	X
DU-14-A	17.5[a]	X	X	X	X	
DU-14-B	17.6	X	X	X	X	
DU-15	17.1	X	X	X	X	X
DU-16	16.3	X	X	X	X	X
DU-17	20.2	X	X	X	X	
P5-01-01	7.8	X	X	X	X	
P5-01-02	7.8	X	X	X	X	
P5-01-03	9.1	X	X	X	X	
P5-01-04	8.5	X	X	X	X	
P5-01-05	3.8					
P5-01-06	11.7	X	X	X	X	
P5-01-07	16.0	X	X	X	X	
P5-01-08	13.6	X	X	X	X	
P5-04-01	16.5	X	X	X	X	
P5-04-02	16.4	X	X	X	X	
P5-04-03	16.3	X	X	X	X	
P5-04-04	12.7	X	X	X	X	
P5-04-05	10.5	X	X	X	X	
P5-04-06	16.5	X	X	X	X	
P5-04-07	14.1	X	X	X	X	
P9-01	13.9	X	X	X	X	
P9-02	15.5	X	X	X	X	X
P9-03	11.5	X	X	X	X	X
P9-04	16.5	X	X	X	X	X
P9-05	16.9	X	X	X	X	
P9-06	14.5	X	X	X	X	X
P9-07	15.8	X	X	X	X	
P9-08	13.5	X	X	X	X	X
P9-09	11.5	X	X	X	X	X
P9-10	9.5	X	X	X	X	X
P9-11	15.0	X	X	X	X	X
P9-12	16.5	X	X	X	X	
P9-13	15.8	X	X	X	X	
P9-14	14.5	X	X	X	X	
P9-15	13.5	X	X	X	X	X
P9-16	13.8	X	X	X	X	X
P9-17	14.8	X	X	X	X	X
P9-18	18.0	X	X	X	X	
P9-19	15.0	X	X	X	X	X
P9-20	12.3	X	X	X	X	X

Table 1. (continued).

Type A Probe	Total Depth (ft)	Geophysical log types				
		PG	NG	PN	MO	AZ
P9-20-01	13.9	X	X	X	X	X
P9-20-02	11.6[a]	X	X	X	X	X
P9-20-03	12.2	X	X	X	X	X
P9-20-04	12.6	X	X	X	X	X
P9-20-05	12.0	X	X	X	X	X
P9-20-06	12.3	X	X	X	X	X
P9-21	4.5					
P9-21A	13.3	X	X	X	X	
P9-22	12.3	X	X	X	X	
P9-23	11.4	X	X	X	X	
P9-24	4.0					
P9-24A	12.7	X	X	X	X	
P9-25	3.5					
P9-25A	11.4	X	X	X	X	
P9-26	5.0					
P9-26A	11.3	X	X	X	X	
P9-27	11.3	X	X	X	X	
P9-28	4.5					
P9-28A	10.1	X	X	X	X	
P9-FI-01	10.1[a]	X	X	X	X	
P9-FI-02	12.1[a]	X	X	X	X	
P9-FI-03	16.3	X	X	X	X	
P9-FI-04	13.2[a]	X	X	X	X	
P9-FI-05	13.2	X	X	X	X	
P9-FI-06	17.9	X	X	X	X	
P9-FI-07	16.0	X	X	X	X	
P9-FI-08	16.2	X	X	X	X	
P9-GR-01	13.7	X	X	X	X	
P9-GR-02	13.8	X	X	X	X	
P9-GR-03	13.8	X	X	X	X	
P9-GR-04	11.5[a]	X	X	X	X	
P9-GR-05	11.5	X	X	X	X	
P9-GR-06	11.2	X	X	X	X	
P9-GR-07	12.8[a]	X	X	X	X	
TP-01	9.5		X		X	
TP-02B	17.0		X		X	
TP-03	14.5		X		X	

a. The indicated value is less than the maximum logging depth.

2.2 Type A Probe Tasks

The Type A probes were installed and logged during nine separate tasks, each with specific objectives. The task areas are shown in Figure 3 and the following sections contain brief task summaries. The term "standard logging suite" as used in these sections refers to the combination of (1) passive spectral gamma logging, (2) neutron-activated spectral gamma logging, (3) neutron-neutron moisture logging, and (4) passive neutron logging.

2.2.1 Pit 9 Preliminary Campaign

The Pit 9 preliminary campaign was part of the Pit 9 Stage 1 Subsurface Exploration and Treatability Study[d] and involved installing and logging three Type A probes outside the southeast Pit 9 boundary. The Pit 9 preliminary campaign was undertaken to help address safety concerns prior to probe installation in waste areas. The probes were installed with the intention of penetrating typical Pit 9 soil conditions while avoiding waste. Moisture and n-gamma logging surveys were conducted in these probes as a means to assess general soil conditions with particular emphasis on soil moisture.

2.2.2 Pit 9 40 × 40 Campaign

The Pit 9 40 × 40 campaign (Beitel et al. 2000; Josten and Okeson 2000) was part of the Pit 9 Stage 1 subsurface exploration and treatability study (see footnote d below) and was conducted as a detailed subsurface investigation of a selected area within Pit 9. The 12 × 12-m (40 × 40-ft) study area was selected based on waste inventory information and surface geophysical data, which indicated that the area could contain a high percentage of drums from the Rocky Flats Plant in Colorado. Twenty Type A probes were installed and logged using the full standard geophysical logging tool suite plus several azimuthal logs. The primary objective of logging data analysis was to select a location within the 12 × 12 m (40 × 40-ft) study area to perform a limited excavation and waste retrieval.

2.2.3 Pit 9 Campaign 1

Pit 9 Campaign 1 was part of the Pit 9 Stage 1 Subsurface Exploration and Treatability Study (see footnote d) and involved the installation of eight additional probes to the north of the 12 × 12-m (40 × 40-ft) campaign study area. Five of these probes met refusal at depths no greater than 1.5 m (5 ft) and were replaced by new probes located several feet away. All Campaign 1 probes were logged with the standard logging suite. These probes were intended to evaluate conditions just north of the 12 × 12-m (40 × 40-ft) study area, which was being considered as the best location for the planned waste excavation and retrieval.

2.2.4 Pit 9 Campaign 2

Pit 9 Campaign 2 was part of the Pit 9 Stage 1 Subsurface Exploration and Treatability Study (see footnote d) and consisted of two probe arrays, one located in the northern part of Pit 9 and one located along the southeast pit boundary. The northern array included eight probes and was intended to explore

d. INEEL, 2000, "OU 7-10 Stage I Subsurface Exploration and Treatability Studies Report (Draft), Initial Probing Campaign (December 1999–June 2000)," INEEL/EXT-2000-00403, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho, July 2000.

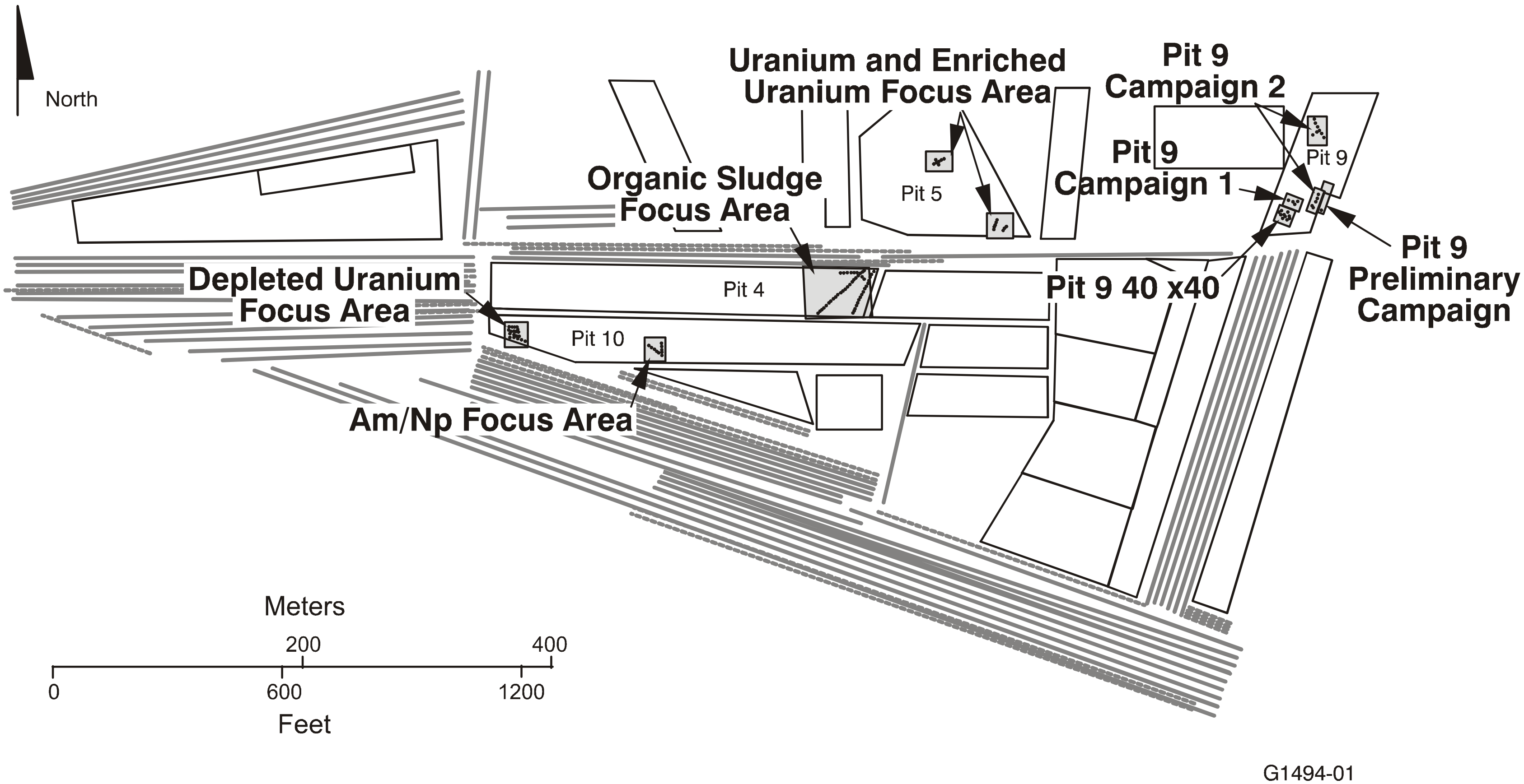

Figure 3. Location map for Type A logging probe campaigns.

for Pu-239-bearing, high-efficiency particulate air (HEPA) filters from the Rocky Flats Plant. The southern array consisted of seven probes and was intended to explore for Pu-239-bearing graphite molds from Rocky Flats. In both cases, the search locations were selected using waste inventory records and surface geophysical data. All Campaign 2 probes were logged with the standard logging suite.

2.2.5 Depleted Uranium Focus Area

Depleted uranium focus area probing was conducted as part of the SDA Probing Project[e] and consisted of an initial eight-probe array installed in the extreme western end of Pit 10. Nine additional probes then were installed to provide more detail. All depleted uranium focus area probes were targeted to intersect Rocky Flats Plant waste shipments containing depleted uranium. The main objective was to identify candidate zones for in situ studies of uranium release into the vadose zone. Depleted uranium focus area probe locations were selected based on surface geophysics and waste inventory records, and were logged with the standard logging suite, plus selected azimuthal logging.

2.2.6 Americium and Neptunium Focus Area

Americium and neptunium focus area probing was conducted as part of the SDA Probing Project (see footnote e) and consisted of nine probes installed in the west-central portion of Pit 10. Of these nine probes, three could not be driven past a total depth of 1.9 m (6.3 ft) because of the presence of a resistive subsurface layer and, therefore, were not logged. The americium and neptunium focus area probes were targeted to intersect Rocky Flats Plant waste shipments containing Pu-239, Am-241, and Np-237 in the form of 741-series waste sludge. The main objective was to identify candidate zones for in situ studies of plutonium, americium, and neptunium release into the vadose zone. Americium and neptunium focus area probe locations were selected based on surface geophysics data and waste inventory records. Probes were logged with the standard logging suite, plus selected azimuthal logging.

2.2.7 Organic Sludge Focus Area

Organic sludge focus area probing was conducted under the SDA Probing Project (see footnote e, p. 11) and consisted of 36 probes installed in the eastern end of Pit 4. Twenty-seven of these probes are in a line and form a continuous profile from northeast to southwest across the eastern end of Pit 4. The remaining nine probes were installed to investigate possible areas for a pilot-scale remediation study. Of these 36 total probes, one could not be driven past a total depth of 1.3 m (4.2 ft) because of the presence of a resistive subsurface layer and therefore was not logged. The 743 sludge focus area probes were intended to intersect Rocky Flats Plant 743-series sludge waste shipments containing volatile organic compounds (VOCs). The objective was to evaluate the credibility of current VOC mass estimates for the SDA. This objective would be achieved by a detailed in situ study of chlorinated solvents using probe logging data, leachate samples, soil vapor measurements, and shipping records. Target locations for organic sludge focus area probes were selected based on surface geophysics and waste inventory records. Probes were logged with the standard logging suite, plus selected azimuthal logging.

2.2.8 Uranium and Enriched Uranium Focus Area

Uranium and enriched-uranium focus area probing was conducted as part of the SDA Probing Project and consisted of an eight-probe array installed near the southeast corner of Pit 5 and a seven-probe

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e. Holdren, K. Jean, Becker, Bruce H., Nancy L. Hampton, L. Don Koeppen, Swen O. Magnuson, T. J. Meyer, Gail L. Olson, and A. Jeffrey Sondrup, 2002, "Waste Area Group 7 Operable Unit 7-13/14 Pre-Draft Remedial Investigation and Baseline Risk Assessment (Draft)," DOE/ID-10995, Rev. C, U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho, April 2002.

array installed in the central portion of Pit 5. The eight-probe array targeted waste shipments containing U-233. The seven-probe array targeted waste shipments containing highly enriched uranium. The objective in both cases was to verify the presence of these waste forms. Target locations for Pit 5 probes were selected based on surface geophysics data and waste inventory records. Probes were logged with the standard logging suite.

2.2.9 Cluster Probes

A series of tightly spaced probe clusters at several locations in Pits 4, 9, and 10 were installed as part of the SDA Probing Project (see footnote e, p. 11) to support quantitative analysis objectives. The probe clusters were designed so that the geophysical investigation area from adjacent probes would overlap, providing necessary data redundancy to constrain quantitative modeling efforts. The probe cluster locations were selected based on geophysical logging results from the initial logging campaigns, which identified preferred locations for detailed study of Np-237, Am-241, Pu-239, U-235, and U-238 contamination zones. Probes were logged with the standard logging suite, plus selected azimuthal logging.

2.3 Data Acquisition

The downhole geophysical logging systems used in Type A probe logging at the SDA consist of a vehicle, a cable and winch mechanism, logging tools, and support electronics.

2.3.1 Description of Logging Vehicle

The logging vehicle provides a mobile, self-contained logging capability that is suitable for storing geophysical logging tools when not in use. The cable and winch mechanism positions the logging tool over the probehole, raises and lowers the tool during logging, and provides communication between the tool and the truck electronics. The data acquisition electronics control cable and winch motions, initiate and control logging measurements, and store data.

Two separate logging vehicles were employed for downhole logging at the SDA. One vehicle is owned by DOE-Hanford and the second is owned by the U.S. Department of Energy Idaho Operations Office (DOE-ID). Both systems were manufactured by Greenspan, of Houston, Texas, for use at DOE nuclear waste sites. Further details about the logging systems may be obtained from the GTS Duratek report included as Appendix A and in Josten and Okeson (2000).

Both the Hanford and INEEL logging systems transmit an analog signal through the full length of the logging cable before the signal is digitized by electronics in the logging truck. The analog signal is subject to noise influences depending on the length of the cable and other details such as types and locations of cable connectors. Because of these factors, the logging cable and support electronics have a significant influence on logging tool response. Tool calibration accounts for the combined effect of the logging tool response and the logging system influence. For this reason, logging tools must be calibrated for each logging system used and must be recalibrated if a logging system is materially altered. For the SDA logging program, three unique logging systems are identified as shown in Table 2. Each logging measurement obtained during SDA Type A probe logging is associated with only one of the system identifiers listed in Table 2.

Table 2. Logging system summary.

System Identification	Logging Vehicle	System Configuration
HO-68B-3573	Hanford	600-ft cable
HO-68B-3573-SHORT	Hanford	100-ft cable
INEEL van	INEEL	100-ft cable

INEEL = Idaho National Engineering and Environmental Laboratory

2.3.2 Description of Logging Tools

The downhole geophysical logging program relied on a standard four-tool logging suite consisting of passive spectral gamma, passive neutron, neutron-activated gamma, and soil moisture logs. The full set of standard measurements was obtained for 135 probes. Only a partial logging suite was obtained for the three probeholes in the Preliminary Pit 9 Campaign, and 10 probes were not logged because of shallow probe penetration. For 30 probeholes, the standard measurements were supplemented by azimuthal gamma measurements.

Table 3 is a list of general specifications for the logging tools used during the SDA logging program. Note that at least two different versions were used for each logging tool, either because duplicate instruments were employed or because the tools were modified during the course of the logging program. A unique identifier, Tool_ID, was assigned to each separate logging tool version so that the tool used for any measurement at the SDA can be positively identified. The purpose and configuration of the logging tools are described briefly below. More detailed descriptions may be obtained from GTS Duratek reports (see Appendix A; and Josten and Okeson 2000).

2.3.3 Passive Spectral Gamma

The passive gamma logging tool relies on a 35% high-purity germanium (HPGe) gamma detector. The detector, cooling system, and electronics are contained in a steel tool string having a maximum diameter of 9.21 cm (3.625 in.) The center of the detector was mounted 76.2 cm (30 in.) from the logging tool end plug during early deployment at Pit 9, but later was changed to 10 cm (4 in.) to support measurements closer to the bottom of the probeholes. At each measurement point, the passive gamma-logging tool produces a spectral summary showing the number of gammas measured as a function of gamma energy. Specific radionuclides are identified by their characteristic gamma energies or those of their daughter products.

2.3.4 Neutron-Activated Spectral Gamma

Neutron-activated gamma (n-gamma) logging employs a gamma spectrometer combined with a neutron source on the same tool string. The neutron source produces a neutron cloud in the vicinity of the probehole and the gamma spectrometer detects gammas emitted during neutron capture reactions. The tool's HPGe detector measures gamma flux as a function of energy. Certain elements (such as chlorine) that have a high affinity for neutron capture may be detected based on their characteristic capture gammas. The n-gamma tool used at the SDA employs a 6.9 μg Cf-252 source mounted immediately above the tool end plug with the HPGe detector located 41 cm (16 in.) above the source. Elements detected during n-gamma logging at the SDA include chlorine, iron, calcium, silicon, and hydrogen. Chlorine measurements were sought as an indicator for chlorinated VOCs. However, chlorine from other sources (e.g., plastics) cannot be distinguished from VOCs. Iron, calcium, silicon, and hydrogen provide information on the soil and waste matrix properties.

Table 3. Logging tool specifications.

Tool Identification	Description	Contractor Tool Identification	Source	Detector	Diameter (in.)	Length (ft)	End Plug to Detector Offset (in.)
PG-1	Passive spectral gamma	RLSG035N00L00.0[a]	None	35% HPGe	3.625	6.79	30
PG-2	Passive spectral gamma	RLSG035A00S00.0	None	35% HPGe	3.5	4.3	4
PN-1	Passive neutron	RLSPN1.0[a]	None	2 in. x 12 in. helium-3	3.625	6.79	9
PN-2	Passive neutron	RLSPN1.0	None	2 in. x 12 in. helium-3	3.5	2.58	6
NG-1	Neutron-activated spectral gamma	RLSG018NS00N00.0	Cf-252[b]	18% HPGe	3.5	5.87	16
NG-2	Neutron-activated spectral gamma	RLSG020NS00N00.0	Cf-252[2]	20% HPGe	3.5	5.87	16
Moi-1	Neutron-neutron moisture	RLSM00.0	Am/Be [c]	1 in. x 5.2 in. helium-3	1.5	1.3	3
Moi-2[d]	Neutron-neutron moisture	RLSM10.0	Am/Be[c]	1 in. x 5.2 in. helium-3	1.5	1.3	3
Moi-2[d]	Neutron-neutron moisture	RLSM10.1	Am/Be[c]	1 in. x 5.2 in. helium-3	1.5	1.3	3
AZ-1	Azimuthal gamma	RLSG01000A00.0	None	10% HPGe	4.25	5.0	9
AZ-2	Azimuthal gamma	RLSG01800A01.0	None	18% HPGe	4.25	4.2	4

HPGe = high-purity germanium.

a. RLSG035N00L00.0 and RLSPN1.0 were combined on the same tool string for simultaneous logging.

b. The Cf-252 source (Source No. FTC-CF-690) had a mass of 6.857 mg.

c. The source activity for americium/beryllium was 50 mCi.

d. RLSM10.0 and RLSM10.1 refer to the same tools. Tool_ID “RLSM10.1” was mistakenly entered instead of “RLSM10.0” during data acquisition from September 8, 2000, to November 30, 2000 (see Table 4), and, therefore, shows up in spectral file headers for moisture data sets collected during that period.

2.3.5 Neutron-Neutron Moisture

The neutron-neutron moisture-logging tool used for SDA operations incorporates a 50-mCi americium-beryllium neutron source to irradiate the soil near the probehole and a helium-3 detector to measure thermal neutron flux at a fixed distance from the source. Neutron moisture tools operate on the assumption that hydrogen atoms constitute the principal neutron moderator in the soil formation and that hydrogen is present mainly in the form of water. The moisture logging tools used in the SDA logging programs are of the close-spaced type, which means that measured count rate increases with increasing hydrogen content. The SDA logging tool employs a 3 × 13.2 cm (1 × 5.2 in.) helium-3 detector with its center located 7.6 cm (3 in.) above the tool end plug. The instrument measures count rate as a function of energy, but energy information is discarded during processing to produce a single value representing total counts per unit time.

2.3.6 Passive Neutron

Passive neutron logging employs a downhole thermal neutron detector to detect neutrons emitted by spontaneous fission and alpha-neutron reactions initiated by radionuclides within buried waste. The passive neutron-logging tool used at the SDA employs a 5 × 12-cm (2 × 12-in.) helium-3 detector. During early measurements at Pit 9, the passive neutron tool was combined on the same tool string with the passive gamma tool, but subsequently was deployed as a completely separate tool. At each measurement point, the passive neutron logging tool measures count rate as a function of energy, but energy information is discarded during processing to produce a single value representing total counts per unit time. The resulting bulk count rate corresponds to the steady-state neutron flux through the probehole casing at the measurement point. High neutron flux is interpreted to mean elevated Am-241 and plutonium levels.

2.3.7 Azimuthal Spectral Gamma

The azimuthal gamma-logging tool consists of a 10% HPGe gamma spectrometer, fitted with a windowed shield. After initial surveys at Pit 9, the azimuthal tool was refitted with an 18% HPGe detector and an improved shield.[f] Most gammas from buried waste are effectively blocked from reaching the detector by the shield. Some gammas from buried waste pass through the shield window and are detected as a function of energy. Azimuthal gamma logging is performed by rotating the detector, window, and shield incrementally around the probehole and measuring a gamma spectrum at each azimuthal position. The tool permits differentiation between uniformly distributed radionuclides and radionuclides distributed as concentrated localized sources. The azimuth of the highest gamma response indicates the direction of the localized source.

In a typical azimuthal survey measurements initially are obtained at 45-degree angular increments to identify general source direction. Additional measurements then are obtained at intermediate angles to refine the source location.

f. The new shield was constructed from 1.8-cm (0.7-in.) thick alloyed tungsten and provided improved gamma-ray attenuation compared with the original shield having 2.1-cm (0.825-in.) thick mild steel.

3. DATA PROCESSING

This section provides a review of the data processing steps applied by GTS Duratek and information on the steps by which raw detector output is converted to final processed values. Both the raw detector output, in the form of spectral files, and the final processed values eventually will be stored in a comprehensive database maintained at the INEEL. Additional information relating to theory and mechanics of data processing may be obtained from the GTS Duratek report in Appendix A.

3.1 Standard Data Processing

The raw output from each logging tool is a count spectrum, which gives total counts as a function of channel number. Standard data processing converts these spectral files to values that may be used to interpret the physical, chemical, and radiological conditions near the probehole. The steps in standard data processing are as follows:

Step 1. Convert channel numbers to corresponding gamma energy values (HPGe detectors only)

Step 2. Determine net peak count rate for each photopeak of interest by performing a background subtraction (HPGe detectors) or sum counts over entire spectrum (neutron detectors)

Step 3. Perform dead time, hole size, and casing thickness corrections (if necessary) to obtain fully corrected net peak count rate

Step 4. Apply calibration function to fully corrected net peak count rate to obtain quantity of interest

Step 5. Apply corrections to calibration (if necessary)

Step 6. Collect results into summary spreadsheet form.

Table 4 summarizes these steps as they pertain to each of the SDA logging tools. The steps are discussed below in the context of each logging tool.

Table 4. Standard processing steps for Subsurface Disposal Area logging data.

Step	Passive Spectral Gamma	Neutron-Activated Spectral Gamma	Neutron-Neutron Moisture	Passive Neutron	Azimuthal Gamma
1. Channel to energy conversion	Based on K-40, U-235, and Th-232 (KUT) peaks	Based on hydrogen and iron peaks	None	None	Based on KUT peaks
2: Peak evaluation	Automatic peak finder, linear background	Automatic peak finder, linear background	Sum counts over entire spectrum	Sum counts over entire spectrum	Automatic peak finder, linear background
3. Peak corrections	Dead time, hole size, casing thickness	Dead time, hole size, casing thickness	Dead time, hole size, casing thickness	None	None
4. Calibration function	$C = \frac{\varepsilon(E) * P}{N}$	$C = k_n P_n f_n$	$V = aP^{\alpha}$	None	None
5. Calibration corrections	None	None	Density correction	None	None
6. Summary	Spreadsheet format	Spreadsheet format	Spreadsheet format	Spreadsheet format	Spreadsheet format

3.1.1 Passive Spectral Gamma Processing

Channel-to-energy conversion for the passive spectral gamma tool is done through a process called energy calibration. A weak radioactive source containing K-40, U-238, and Th-232 (referred to as a KUT source) is attached to the logging tool, and spectra are collected before probehole logging. The process is repeated after logging is complete. These spectra contain KUT peaks at known energies.[g] The energy calibration spectra are used to assign energy values to the channels containing the KUT peaks. Energy values for the remaining channels are interpolated based on the KUT channels. The function that maps channel number to gamma energy is applied to all spectra collected during a logging run. The GTS Duratek procedures describe this process in detail (see Appendix B).

The GTS Duratek software then performs a scan of the energy-indexed spectral files to locate photopeaks. When a peak is found, software automatically determines a linear background. Peak area (i.e., the total net counts forming the peak), background count rate, and peak area counting uncertainty are compiled for each energy peak. A standard count uncertainty is determined using the following relation:

$$unc\% = 100 * \frac{\sqrt{p_g * t_L + \sigma_b^{\,2}}}{p_{net} * t_L} \tag{1}$$

where

p_g is the total count rate (peak plus background)

p_{net} is the net count rate; t_L is the detector livetime (count duration)

σ_b is the background uncertainty.

Net count rates are then corrected for dead time, hole size, and casing thickness to arrive at a fully corrected net peak count rate.

In some cases, two radionuclides can produce gammas having energies so similar that they are indistinguishable in the spectra and they merge to form a common peak. Two such cases were identified in the SDA by the GTS Duratek logging data: 662 keV gammas from Cs-137 and Am-241, and 312 keV gammas from Pa-233, Am-241, and Pu-239. The GTS Duratek took special steps to analyze these gammas (see Appendix A). No other gamma interferences were considered for special analysis.

For gamma peaks having a known association to a specific radionuclide, a calibration function is applied to the fully corrected net count peak rate to compute apparent radionuclide concentrations in picocuries per gram. For gamma peaks that have not been associated with a radionuclide, the calibration relation is not applied and the fully corrected net count peak rates are stored in counts-per-second form.

No further calibration corrections are applied for passive spectral gamma logging. Processed results are reported in a spreadsheet format with one record for each measurement point. The record contains computed radionuclide concentrations and uncertainty values along with auxiliary information such as the Type A probe name, depth, logging date, and the associated spectral file name.

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g. The energy calibration spectra will be included in the comprehensive logging database.

Target radionuclides are not detected for all depths. In these cases, the summary spreadsheets contain blank spaces to indicate that the corresponding radionuclide was below the logging system detection limit.

3.1.2 n-Gamma Processing

Channel-to-energy conversion for the n-gamma tool is performed using hydrogen and iron capture gammas, which are ubiquitous in the logging spectra because of soil moisture and steel borehole casing. After assigning energy values to hydrogen and iron peaks, energies are interpolated for the remainder of the channels. Spectral peaks are then detected, and peak heights and uncertainties are quantified by the same methods as used for spectral gamma data. Dead time, hole size, and casing corrections also are applied as for passive spectral gamma logging, resulting in a final set of fully corrected net peak count rates for each measurement location. The GTS Duratek procedure for n-gamma data acquisition and processing is included in Appendix B.

As explained further in Section 5, n-gamma calibration for chlorine peaks was found to be valid only at low chlorine concentrations. For this reason, all n-gamma peaks, including chlorine (in counts-per-second form), will be retained until further calibration studies can be completed.

Processed n-gamma logging results are reported in a spreadsheet format with one record for each measurement point. The record contains capture gamma peak count rates and uncertainty values along with auxiliary information such as Type A probe name, depth, logging date, and the associated spectral file name.

3.1.3 Neutron-neutron Moisture

Channel-to-energy conversion is not performed for moisture data. Instead, GTS Duratek software determines a total count rate for all channels combined (i.e., treating the entire spectrum as a single peak). A single peak area and background count rate is compiled for each measurement spectrum. Net count rates are then corrected for dead time, hole size, and casing thickness. The GTS Duratek procedure for neutron-neutron moisture data acquisition and processing is included in Appendix B.

A calibration function is applied to the fully corrected net peak count rate to compute moisture content in units of volume%.

Processed neutron-neutron moisture results are reported in a spreadsheet format with one record for each measurement point. The record contains the computed volumetric moisture content and uncertainty value, along with auxiliary information such as Type A probe name, depth, date, and the associated spectral file name.

3.1.4 Passive Neutron

Channel-to-energy conversion is not performed for passive neutron data. Instead, GTS Duratek software determines a total net peak count rate for all channels combined (i.e., treating the entire spectrum as a single peak). The net count rate then is corrected for dead time to obtain the fully corrected net peak count rate. Because the passive neutron measurement is used for qualitative purposes only, no corrections are performed for hole size or casing thickness. No calibration corrections are applied. The GTS Duratek procedure for passive neutron data acquisition and processing is included in Appendix B.

Processed passive neutron logging results are reported in a spreadsheet format with one record for each measurement point. The record contains the fully corrected net peak count rate and uncertainty value along with auxiliary information such as Type A probe name, depth, date, and the associated spectral file name.

3.1.5 Azimuthal Spectral Gamma

Channel-to-energy conversion, peak detection, and calculation of net peak count rate for the azimuthal tool are performed by the same methods used for passive spectral gamma data. Azimuthal data are used for qualitative purposes only and, therefore, no corrections are performed for hole size or casing thickness. Dead-time corrections are applied to obtain the fully corrected net peak count rate. No calibration corrections are applied. The GTS Duratek procedure for azimuthal gamma data acquisition and processing is included in Appendix B.

Processed azimuthal logging results are reported in a spreadsheet format with one record for each measurement point. The record contains the fully corrected net peak count rate for all detected gamma peaks, uncertainty values, and auxiliary information such as Type A probe name, depth, azimuth angle, and the associated spectral file name. Azimuth angles are measured clockwise relative to true north, which is marked on the probehole casing.

4. LOGGING TOOL CALIBRATION

Tool calibration functions are needed to convert raw tool measurements (in counts per second) into desired quantitative parameters such as moisture content in volume% or radionuclide concentrations in picocuries (or nanocuries) per gram. Calibration functions are applied during data processing as described in Section 5. This section provides a discussion of calibration activities, summaries of calibration data and functions, and information needed to determine the appropriate calibration data for any of the thousands of SDA logging measurements.

Calibration functions are developed through rigorous measurement programs that use physical borehole models having known attributes that simulate the expected field conditions. Tool calibration is required only for tools that produce quantitative results. In the case of the SDA Probing Project, calibration functions were developed only for the passive spectral gamma, neutron-neutron moisture, and neutron-activated gamma tools.[h]

Logging tools are recalibrated as follows:

- Annually, as required by GTS Duratek procedures
- After installing a new radioactive source (active tools only)
- After a physical modification to the tool or logging truck.

Table 5 is a list of GTS Duratek calibration records applicable to the SDA Probing Project. For archive purposes, each calibration record has been assigned a unique calibration record identification. Calibration certificates supplied by GTS Duratek and associated with these calibration records are reproduced in Appendix C.

Table 5. Tool calibration record summary.

Calibration Identification	Tool Identification	Date	Logging System	Notes
Moisture				
Cal_Moi_1	Moi-1	May 13, 1999	HO-68B-3573	6 and 8-in. hole diameter[a]
Cal_Moi_2	Moi-2	November 19, 1999	HO-68B-3573	6 and 8-in. hole diameter[a]
Cal_Moi_3	Moi-2	August 22, 2000	HO-68B-3573-SHORT	5.5-in. hole diameter
Cal_Moi_4	Moi-2	August 28, 2000	INEEL van	5.5-in. hole diameter
Spectral Gamma				
Cal_PG_1	PG-1	January 19, 1999	HO-68B-3573	Standard calibration
Cal_PG_2	PG-2	August 24, 2000	INEEL van	Standard calibration
n-Gamma				
Cal_NG_1	NG-1	February, 22, 1999	HO-68B-3573	Standard calibration
Cal_NG_2	NG-2	January 7, 2000	HO-68B-3573	Standard calibration
Cal_NG_3	NG-2	August 29,2000	HO-68B-3573-SHORT	Saltwater tank calibration

INEEL = Idaho National Engineering and Environmental Laboratory
a. Values for a 14-cm (5.5-in.) hole diameter were interpolated from data for 15 and 20-cm (6 and 8-in.) hole diameters, but are not shown in the calibration records.

h. Some miscellaneous additional GTS Duratek measurement records are included in Appendix C.

Table 6 provides a cross-reference between SDA Probing Project logging data and applicable calibration records. For cross-reference purposes, each SDA Probing Project logging measurement uniquely is specified by the combination of three parameters: logging date, tool identification, and logging system.

Table 6. Tool deployment summary.

Tool Identification	GTS Duratek Identification	Use Dates	Probeholes Logged	Calibration Records[a]
n-Gamma				
NG-1	HO-68B-3573	June 30, 1999	TP-01, TP-02B, and TP-03	Cal_NG_1
NG-2	HO-68B-3573	January 24, 2000 to February 2, 2000	P9-01 to P9-20	Cal_NG_2
NG-2	HO-68B-3573-SHORT	September 9, 2000 to July 24, 2000	All other probes	Cal_NG-3
Spectral Gamma				
PG-1	HO-68B-3573	January 13, 2000, to January 27, 2000	P9-01 through P9-20	Cal_PG_1
PG-2	INEEL van	September 10, 2000, to July 23, 2001	All other probes	Cal_PG_2
Moisture				
Moi-1	HO-68B-3573	June 29, 1999, to June 30, 1999	TP-01, TP-02B, and TP-03	Cal_Moi_1
Moi-2	HO-68B-3573	January 11, 2000, to January 13, 2000	P9-01 through P9-20	Cal_Moi_2
Moi-2	HO-68B-3573-SHORT	November 16, 2000 to January 27, 2001	743-07 through 743-10 743-14 through 743-23 743-32 and 743-33 DU-09 though DU-17	Cal_Moi_3
Moi-2	INEEL van	September 8, 2000, to July 19, 2001	P9-20R through P9-28A All P9-FI probes All P9-GR probes DU-01 through DU-08 741-02 through 741-09 743-11 through 743-13 743-24 though 743-42 P9-20 cluster 743-08 cluster DU-08A/B, DU-10A/B, DU-14A/B, and 741-08A/B All Pit 5 probes	Cal_Moi_4

INEEL = Idaho National Engineering and Environmental Laboratory
a. See Table 5.

A detailed discussion of calibration activities for each logging tool may be found in relevant sections of the GTS Duratek report (see Appendix A) and Josten and Okeson (2000). The following sections provide a general summary and present calibration constant for each calibration record in Table 5.

4.1 Passive Spectral Gamma Tool Calibration

Passive spectral gamma logging tools were calibrated assuming the following:

- Uniform soil and radionuclide distribution
- Probes with an outside diameter of 13 cm (5.5 in.) and a steel casing 1.3 cm (0.5 in.) thick
- Independent of soil density for homogenous conditions
- Valid for gamma energy between 150 and 3,000 keV.

To the extent that actual measurement conditions correspond to these assumed conditions, the calibration function converts net count rates to radionuclide concentration in units of activity per unit mass.

Spectral gamma logging uses the following calibration function of the form

$$C = \frac{\varepsilon(E) * P}{N} \tag{2}$$

where

P is the fully corrected net peak count rate (cps)

ε(E) is the efficiency function for the HPGe detector at gamma ray energy E

N is the absolute intensity of a specific radionuclide gamma

C is the computed radionuclide concentration in pCi/g.

The efficiency function has the form

$$\varepsilon(E) = a * E^{\alpha} + b * E^{\beta} \tag{3}$$

where

a, α, b and β are fit coefficients obtained during instrument calibration (Randall 1994).

Fit coefficients for the relevant spectral gamma calibration records are given in Table 7.

Table 7. Spectral gamma calibration constants.

Calibration Identification	a	α	b	β
Cal_PG_1	11.51	0.193	0	0
Cal_PG_2	8.385	0.238	1.01e10	-4.301

4.2 Neutron-Activated Spectral Gamma Tool Calibration

Neutron-activated spectral gamma logging tools initially were calibrated assuming the following:

- Uniform soil, soil moisture, and chlorine distribution
- Probes with and outside diameter of 13 cm (5.5 in.) and a steel casing 1.3 cm (0.5 in.) thick
- A 7 volume% moisture
- Bulk density of 1.8 g/cm^3
- Chlorine up to 1.4 wt%.

The n-gamma logging tool relies on the following calibration function of the form

$$C = \alpha_n P_n f_n \qquad n = 1,2,3 \tag{4}$$

where α_n and f_n are the calibration constants and P_n is the fully corrected net peak count rate for the 1,165 keV, 1,951 keV, and 1,959 keV chlorine peaks, respectively.

Fit coefficients for the relevant n-gamma calibration records are given in Table 8.

Table 8. n-Gamma calibration constants.

Calibration Identification	α_1	α_2	α_3	f_1	f_2	f_3
Cal_NG_1	2190	5150	6730	0.364	0.367	0.367
Cal_NG_2	2200	—	—	0.364	—	—

Because of concerns about the adequacy of the n-gamma calibration functions, n-gamma data were archived as fully corrected net peak count rate rather than as chlorine wt%. An additional calibration study was performed in August 2000 to assess n-gamma tool performance under high chlorine conditions (i.e., greater than 1.4 wt%). The study was undertaken to address observations that the n-gamma logging tool response was clearly nonlinear relative to chlorine content above several weight percent. However, the August 2000 study, which employed a saltwater tank to simulate a high chlorine environment, did not adequately represent SDA field conditions. Records from the August 2000 calibration study are included in Appendix C.

4.3 Neutron-Neutron Moisture Tool Calibration

Neutron-neutron logging tools were calibrated assuming the following conditions:

- Uniform soil and soil moisture distribution
- Probes with an outside diameter of 13 cm (5.5. in.) and a steel casing 1.3 cm (0.5 in.) thick
- Low neutron capture cross section ($\Sigma \cong 0.0004$ cm^{-1})

- Dry bulk density = 1.43 g/cm^3 (after density correction).

The neutron-neutron moisture-logging tool uses the following calibration function of the form

$$V = aP^{\alpha} \tag{5}$$

where

V is the calibrated volume fraction of water (volume%)

P is the fully corrected net peak count rate (cps)

a and α are calibration constants (Meisner et al. 1996).

Fit coefficients for the relevant n-gamma calibration records are given in Table 9.

Table 9. Neutron-neutron moisture tool calibration constants.

Cal_ID	a	α
Cal_Moi_1	Need from GTS Duratek	Need from GTS Duratek
Cal_Moi_2	Need from GTS Duratek	Need from GTS Duratek
Cal_Moi_3	0.0001650	2.134
Cal_Moi_4	0.0002023	2.096

After applying this relation, data were further corrected to account for an assumed dry bulk density of 1.43 g/cm^3 that is based on analysis of 136 SDA soil samples (Borghese 1988; McElroy and Hubbel 1990; McElroy 1993; Schakofsky 1995).

The density correction is applied according to the following formula

$$\frac{V}{V_{app}} = -.657\rho + 2.267 \tag{6}$$

where

V_{app} is the apparent moisture content after applying the appropriate calibration relation

ρ is the formation bulk density

V is the density corrected moisture content (Meisner, Price, and Randall. 1996).

Note that the formation bulk density depends on the assumed dry bulk density (1.43 g/cm^3) and on the moisture content itself according to the relation

$$\rho = \rho_{dry} + V_{app}\rho_{water} \tag{7}$$

The density correction is a recursive relation and is applied iteratively to determine the corrected moisture content value. A single iteration by GTS Duratek made the corrections for SDA moisture logging data.

4.4 Other Calibration Information

Appendix C contains the following additional calibration information:

- Winch cable depth calibration
- n-Gamma saltwater tank calibration
- Azimuthal tool test records.

5. DATABASE AND ARCHIVE

This section makes general recommendations for the construction of the database archive.

All raw logging data and GTS Duratek analysis results eventually will be archived in a comprehensive database constructed and maintained by the INEEL. The database will be constructed to achieve the following two purposes:

1. Retain logging results analyzed by GTS Duratek in a manner that facilitates additional interpretation of the SDA subsurface, as necessary, to address present and future INEEL criteria.

2. Retain original unprocessed data records (and support information) in a manner that facilitates complete reanalysis of all or part of the logging results, if deemed necessary in the future.

5.1 Database

The database should contain eight types of information as listed in Table 10. The detailed structure will be determined as the database is assembled, and descriptive documentation will be developed by the INEEL.

Table 10. Recommended database contents.

Database Table	Contents
Passive spectral gamma	GTS Duratek analysis and spectral file references for passive spectral gamma measurements
n-Gamma	GTS Duratek analysis and spectral file references for n-gamma measurements
Neutron-neutron moisture	GTS Duratek analysis and spectral file references for neutron-neutron moisture measurements
Passive neutron	GTS Duratek analysis and spectral file references for passive neutron measurements
Azimuthal gamma	GTS Duratek analysis and spectral file references for azimuthal gamma measurements
Tool summary	Tool descriptive information
Logging system summary	Logging truck, cable, and data acquisition system descriptive information
Calibration summary	Tool calibration information
Probe locations	Probe locations, depth, construction

Some observations pertaining to the structure of the database include the following:

- Each single calibration record gives calibration constants that are valid under a strict set of conditions. These conditions specify the tool, logging system, and date range for which the calibration applies.

- A 1:1 relationship exists between a logging measurement and its associated calibration record. The combination of tool, logging date, Type A probe name, and logging system uniquely determines the calibration record associated with a logging measurement.

- A 1:1 relationship exists between a logging measurement and its associated spectral file. The only exception to this rule is for Probeholes P9-01 to P9-19, where spectral files contain both passive gamma and passive neutron spectra. Two measurements may have the same tool identification, Type A probe name, logging date, and logging depth but different spectral files. This duplication would occur only if a set of logging measurements were repeated for quality assurance and quality control purposes on the same day.

The electronic records for Type A probe logging data include spectral records, analysis records, and calibration records. These are described in the following sections.

5.1.1 Spectral Data Records

Each measurement by each logging tool is recorded as a single spectral file with a unique file name. These spectral files contain the fundamental measurement data and should be preserved in the database with an appropriate cross-reference to the corresponding analysis results. File names consist of a prefix and suffix, where the prefix is repeated for all files in a single logging run and the suffix is incremented for each new measurement. Prefix values range from “P006” to “PA37” and suffix values range from “1000” to about “1070” or “2000” to about “2070.” There are also files with the suffixes “1BAA,” “1BAB,” and “1CAB,” which were used for detector energy calibration. The spectral files are binary files in standard format.

5.1.2 Analysis Results Records

During GTS Duratek data processing, raw spectral files are analyzed to detect and measure spectral peak heights. These spectral peak heights are related to quantities of interest such as soil moisture or radionuclide concentration. In some cases, calibration functions are applied to peak height data to generate quantitative estimates. In other cases, peak heights in counts-per-second form are the final analysis result.

After analysis, results are compiled into a spreadsheet format and collected by probehole. Each measurement is listed as a unique data record consisting of a series of values including Type A probe name, logging date, logging depth, and a series of peak heights (or quantitative estimates), as appropriate, for each logging tool. Each peak height measurement has an associated uncertainty value computed during analysis. Each record also includes the name of the unique spectral file upon which the record is based. The spreadsheet compilations, one for each logging tool, can serve as the primary source for populating the archive database.

5.1.3 Calibration Records

Calibration records should be stored as image reproductions of the calibration records supplied by GTS Duratek. Database fields should include the applicable logging tool, logging system, and calibration date (see Table 5).

5.1.4 Type A Probe Location Records

Table 1 of this report has been reviewed for consistency with Type A probe records published in the *Data Management Plan for the Operable Unit 7-13/14 Integrated Probing Project* (Salomon 2002, Appendix B) and can be used for populating the archive database. Table 1 contains information on three probes, TP-01, TP-02B, TP-03, that were not included in Salomon (2002) because they were situated in nonwaste areas.

5.1.5 Logging System Records

Table 2 may be used as the basis for developing logging system database records.

5.1.6 Logging Tool Records

Table 3 may be used as the basis for developing logging tool database records.

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